

## CLAIMS

### We claim:

1. A metal oxide material, comprising:  
a metal oxide substrate; and  
a coating bonded to a portion of the metal oxide substrate, the coating comprising an organosilane polymer and the coating having an improved durability.
2. The metal oxide of claim 1, the organosilane comprising a polycarbosilane compound.
3. The metal oxide of claim 2, wherein the polycarbosilane compound is derived from a monomer containing a leaving group selected from halogens, triflates, alkoxy, acyl, oximes, amines, amine salts, or combinations or mixtures thereof.
4. The metal oxide of claim 3, wherein the monomer is alkyl substituted or aromatic substituted.
5. The metal oxide of claim 1, wherein the coating is very stable against hydrolytic cleavage conditions.
6. The metal oxide of claim 1, wherein the metal oxide is silica, titania, zirconia, or a combination thereof.
7. The metal oxide of claim 1, wherein the metal oxide is silica.
8. The metal oxide of claim 7, wherein the silica is used as a packing material or a support material in chromatography.
9. A support composition, comprising:  
a metal oxide substrate; and

a coating bonded to a portion of the metal oxide substrate, the coating comprising an organosilane polymer and the coating having an improved durability.

10. A chromatographic support composition, comprising:

a silica substrate; and

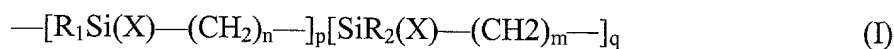
a polycarbosilane coating bonded to a portion of the silica, the polycarbosilane compound derived from an alkyl or aromatic substituted monomer containing a leaving group selected from halogens, triflates, alkoxy, acyl, oximes, amines, amine salts, or combinations or mixtures thereof.

11. A support composition made by the method comprising:

providing a metal oxide substrate; and

providing a coating on a portion of the substrate, the coating comprising an organosilane coating derived from an alkyl or aromatic substituted monomer containing a leaving group selected from halogens, triflates, alkoxy, acyl, oximes, amines, amine salts, or combinations or mixtures thereof.

12. A polydentate silane of the formula (I):



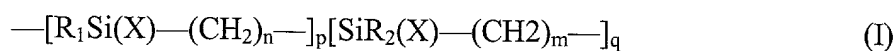
wherein R<sub>1</sub> is an alkyl or aryl group having from 1 to 30 carbon atoms, R<sub>2</sub> is an alkyl or aryl group having from 1 to 30 carbon atoms and may be the same or different than R<sub>1</sub>, R<sub>1</sub> or R<sub>2</sub> include a functional group similar to —(CH<sub>2</sub>)<sub>3</sub>—N<sup>+</sup>Cl<sup>−</sup>, —(CH<sub>2</sub>)<sub>2</sub>—C<sub>6</sub>H<sub>4</sub>—(CH<sub>2</sub>)<sub>3</sub>—C<sub>6</sub>H<sub>4</sub>—SO<sub>3</sub>H, —(CH<sub>2</sub>)<sub>3</sub>—O—CH<sub>2</sub>—CHOH—CH<sub>2</sub>OH, —(CH<sub>2</sub>)<sub>3</sub>—NH<sub>2</sub>, and —(CH<sub>2</sub>)<sub>3</sub>—CN, n is an integer from 1 to 10, m is an integer from 1 to 10, p and q are integers from 0 to 100 (except where p+q=2), and X is a leaving group.

13. The polydentate silane of claim 12, wherein the leaving group is selected from halogens, triflates, alkoxy, acyl, oximes, amines, amine salts, or combinations or mixtures thereof.

14. A chromatographic support composition, comprising:

a silica substrate; and

a polydentate silane of the formula (I) bonded to a portion of the silica substrate



wherein R<sub>1</sub> is an alkyl or aryl group having from 1 to 30 carbon atoms, R<sub>2</sub> is an alkyl or aryl group having from 1 to 30 carbon atoms and may be the same or different than R<sub>1</sub>, R<sub>1</sub> or R<sub>2</sub> include a functional group similar to —(CH<sub>2</sub>)<sub>3</sub>—N<sup>+</sup>Cl<sup>−</sup>, —(CH<sub>2</sub>)<sub>2</sub>—C<sub>6</sub>H<sub>4</sub>—(CH<sub>2</sub>)<sub>3</sub>—C<sub>6</sub>H<sub>4</sub>—SO<sub>3</sub>H, —(CH<sub>2</sub>)<sub>3</sub>—O—CH<sub>2</sub>—CHOH—CH<sub>2</sub>OH, —(CH<sub>2</sub>)<sub>3</sub>—NH<sub>2</sub>, and —(CH<sub>2</sub>)<sub>3</sub>—CN, n is an integer from 1 to 10, m is an integer from 1 to 10, p and q are integers from 0 to 100 (except where p+q=2), and X is a leaving group.

15. The support composition of claim 14, wherein the leaving group of the polydentate silane is selected from halogens, triflates, alkoxy, acyl, oximes, amines, amine salts, or combinations or mixtures thereof.

16. A method of making a metal oxide material, comprising:

providing a metal oxide substrate; and

providing a coating on a portion of the metal oxide substrate, the coating comprising an organosilane polymer and having an improved durability.

17. The method of claim 16, the organosilane comprising a polycarbosilane compound derived from an alkyl substituted or aromatic substituted monomer containing a leaving group

selected from halogens, triflates, alkoxy, acyl, oximes, amines, amine salts, or combinations or mixtures thereof.

18. The method of claim 16, wherein the coating is very stable against hydrolytic cleavage conditions.

19. The method of claim 16, wherein the metal oxide is silica, titania, zirconia, or a combination thereof.

20. The method of claim 19, wherein the metal oxide is used as a packing material or a support material in chromatography.

21. The method of claim 17, including providing the coating by bonding the monomer to the substrate and then polymerizing the monomer.

22. The method of claim 17, including providing the coating by polymerizing the monomer and then bonding the polymer to the substrate.

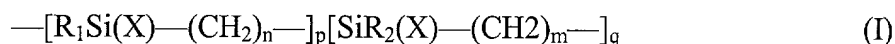
23. A method of making a chromatographic support composition, comprising:  
providing a silica substrate; and

providing a coating on a portion of the silica substrate, the coating comprising a polycarbosilane coating derived from an alkyl or aromatic substituted monomer containing a leaving group selected from halogens, triflates, alkoxy, acyl, oximes, amines, amine salts, or combinations or mixtures thereof.

24. The method of claim 23, including providing the coating by bonding the monomer to the substrate and then polymerizing the monomer.

25. The method of claim 23, including providing the coating by polymerizing the monomer and then bonding the polymer to the substrate.

26. A method of making a coating comprising a polydentate silane of the formula (I)



wherein  $R_1$  is an alkyl or aryl group having from 1 to 30 carbon atoms,  $R_2$  is an alkyl or aryl group having from 1 to 30 carbon atoms and may be the same or different than  $R_1$ ,  $R_1$  or  $R_2$  include a functional group similar to  $-(CH_2)_3-N^+Cl^-$ ,  $-(CH_2)_2-C_6H_4-(CH_2)_3-C_6H_4-SO_3H$ ,  $-(CH_2)_3-O-CH_2-CHOH-CH_2OH$ ,  $-(CH_2)_3-NH_2$ , and  $-(CH_2)_3-CN$ ,  $n$  is an integer from 1 to 10,  $m$  is an integer from 1 to 10,  $p$  and  $q$  are integers from 0 to 100 (except where  $p+q=2$ ), and  $X$  is a leaving group, the method comprising:

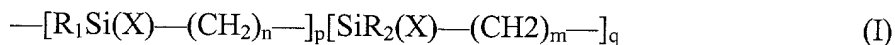
providing a metal oxide substrate;

providing a coating on a portion of the substrate using a monomer containing a leaving group selected from halogens, triflates, alkoxy, acyl, oximes, amines, amine salts, or combinations or mixtures thereof.

27. The method of claim 26, including providing the coating by bonding the monomer to the substrate and then polymerizing the monomer.

28. The method of claim 26, including providing the coating by polymerizing the monomer and then bonding the polymer to the substrate.

29. A polydentate silane coating for a chromatographic support composition comprising a polydentate silane of the formula (I)



wherein  $R_1$  is an alkyl or aryl group having from 1 to 30 carbon atoms,  $R_2$  is an alkyl or aryl group having from 1 to 30 carbon atoms and may be the same or different than  $R_1$ ,  $R_1$  or  $R_2$  include a functional group similar to  $-(CH_2)_3-N^+Cl^-$ ,  $-(CH_2)_2-C_6H_4-(CH_2)_3-C_6H_4-$

$\text{SO}_3\text{H}$ ,  $-(\text{CH}_2)_3-\text{O}-\text{CH}_2-\text{CHOH}-\text{CH}_2\text{OH}$ ,  $-(\text{CH}_2)_3-\text{NH}_2$ , and  $-(\text{CH}_2)_3-\text{CN}$ ,  $n$  is an integer from 1 to 10,  $m$  is an integer from 1 to 10,  $p$  and  $q$  are integers from 0 to 100 (except where  $p+q=2$ ), and  $X$  is a leaving group.

30. A metal oxide material, comprising:

a metal oxide substrate; and

a coating bonded to a portion of the metal oxide substrate, the coating comprising a monomer containing a leaving group selected from halogens, triflates, alkoxy, acyl, oximes, amines, amine salts, or combinations or mixtures thereof.

31. The metal oxide material of claim 30, wherein the wherein the metal oxide is silica, titania, zirconia, or a combination thereof.

32. A metal oxide material, comprising:

a metal oxide substrate; and

a coating bonded to a portion of the metal oxide substrate, the coating comprising a partially-polymerized monomer containing a leaving group selected from halogens, triflates, alkoxy, acyl, oximes, amines, amine salts, or combinations or mixtures thereof.

33. The metal oxide material of claim 32, wherein the wherein the metal oxide is silica, titania, zirconia, or a combination thereof.

34. A chromatographic support composition, comprising:

a silica substrate; and

a coating bonded to a portion of the metal oxide substrate, the coating comprising a monomer containing a leaving group selected from halogens, triflates, alkoxy, acyl, oximes, amines, amine salts, or combinations or mixtures thereof.

35. A chromatographic support composition, comprising:

a silica substrate; and

a coating bonded to a portion of the metal oxide substrate, the coating comprising a partially-polymerized monomer containing a leaving group selected from halogens, triflates, alkoxy, acyl, oximes, amines, amine salts, or combinations or mixtures thereof.

36. A chromatography system containing a support material comprising:

a metal oxide substrate; and

a coating bonded to a portion of the metal oxide substrate, the coating comprising an organosilane polymer and the coating having an improved durability.

37. A method of using a chromatographic support material, comprising:

providing a support material including a metal oxide substrate and a coating bonded to a portion of the metal oxide substrate, the coating comprising an organosilane polymer and the coating having an improved durability; and

using the support material in a chromatography column to analyze the composition of an unknown material.

38. A chromatographic apparatus, comprising a support material including a metal oxide substrate and a coating bonded to a portion of the metal oxide substrate, the coating comprising an organosilane polymer and the coating having an improved durability.